# Virtual casting and rolling lines development

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**Abstract.** The article describes an example of a casting and rolling complex. A program has been developed for calculating the temperature of the metal in the casting and rolling complex sites which is based on a mathematical model for controlling the water cooling of a rotary mold in TIA Portal software using an S7-1200 microprocessor controller. Presents the structure and user interface of the program. The program blocks of the rotary mold, as well as the section of water and air cooling are developed, which include design and thermophysical parameters necessary for calculating according to the mathematical model. In this way, the replacement of any of them with a similar one with modified parameters is possible without making changes to the program structure. The program can be used to debug control algorithms.


## 1. Technological description of the object

Modeling of casting and rolling complexes for solving control problems is an urgent task, since ensuring the optimum temperatures of the metal before rolling leads to an improvement in product quality, as well as an increase in productivity[1, 2].

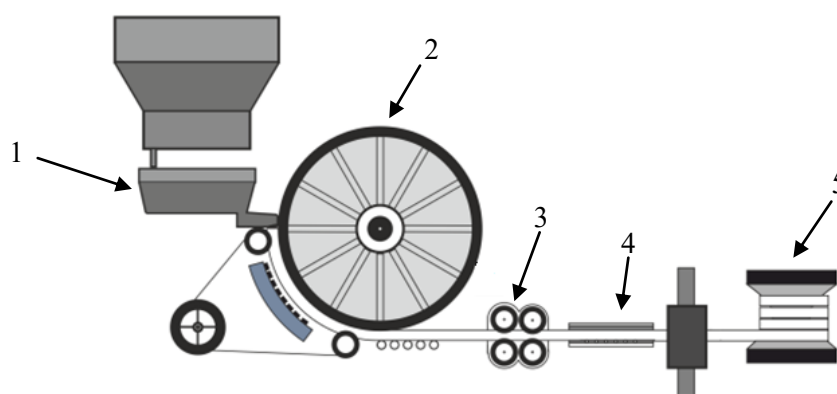Consider the example of a casting and rolling complex (Figure 1).



Figure 1. An example of a casting and rolling complex

In general, the casting and rolling complexes, which include a rotary mold, consist of: a ladle for metal tapping onto the casting wheel 1; mold 2 which is a rotating belt wheel with a notch of trapezoidal section on the rim and pressed onto the rim of an endless steel tape; a water-cooled wedge for the extension of the continuous cast billet; rollers correct device 3 through which the billet passes; cooling zones 4; device for temperature equalization across the section; break-down mill in which a square semi-finished product is formed from trapezoidal billet; storage device 5, on which the obtained rod is wound [3].

Earlier, we developed models of heat exchange and metal movement in the mold of a crimping stand, in the cooling and winding system, based on ordinary differential equations [4, 5]. Development of programs for the calculation on these models will allow you to visualize the rolling process, as well as debug control algorithms on a virtual model, determine the optimal process parameters for various alloys.

## 2. Program structure

The structure of the developed program is presented in Figure 2. The program block FC5 is designed to select the alloy from which the rod will be obtained. The program block FB1 of the rotary mold performs the calculation of the temperatures of the casting wheel and the billet; includes the design parameters as well as the thermophysical parameters of the material from which it is made. In this way, if this block is replaced with another block of rotor mold with other design and thermophysical parameters, the program structure will not change.
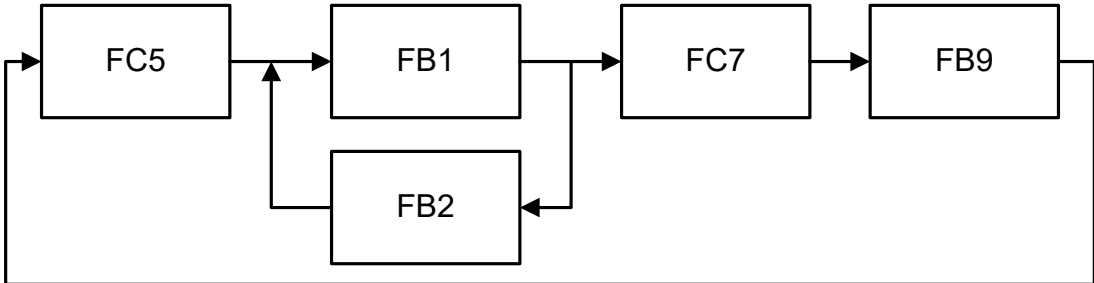
Figure 2. Program flow chart

The program block FB2 serves to control the water consumption to cool the rotary mold [6]. Carries out the calculation of water consumption for cooling within the prescribed limits by a simple procedure of optimization , based on the required temperature of the cast billet at the exit of the mold. The program block FC7 is designed to calculate the temperature of the rod in air and water cooling after the billet leaves the rotary mold. The software block FB9 contains the design parameters of the storage device and calculates its rotational speed depending on the speed of the bar arrival and the number of rolled wire layers wound on the storage device.

## 3. Interface and program functionality

In the TIA Portal software product based on the S7-1200 controller [7], a mathematical model of a rotary mold was implemented by software. The user interface of the program consists of several windows.

Figure 3 shows the general scheme of the process. The user interface allows you to: turn calculation on the model; turn on or turn off the water cooling of the mold; see the calculated values of the bar temperature at the exit of the mold, after the cooling section.
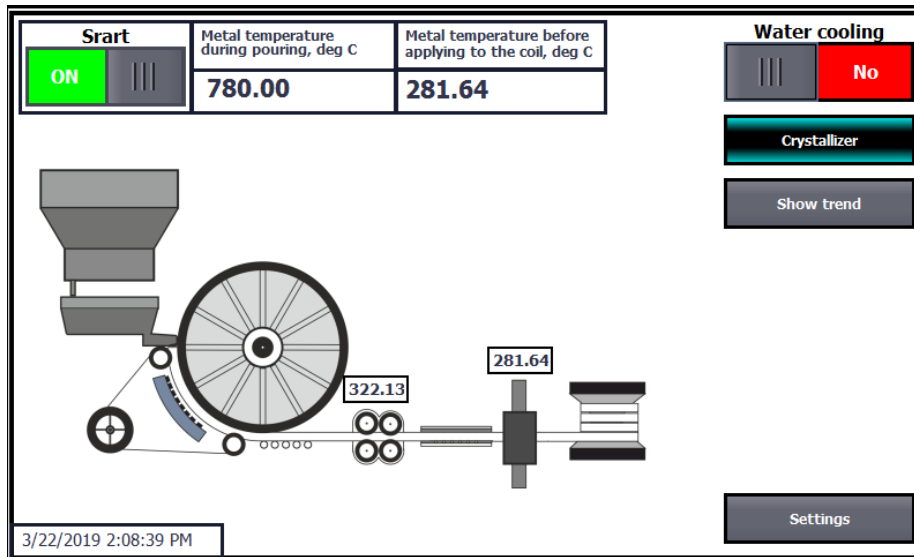
Figure 3. Initial window of the program

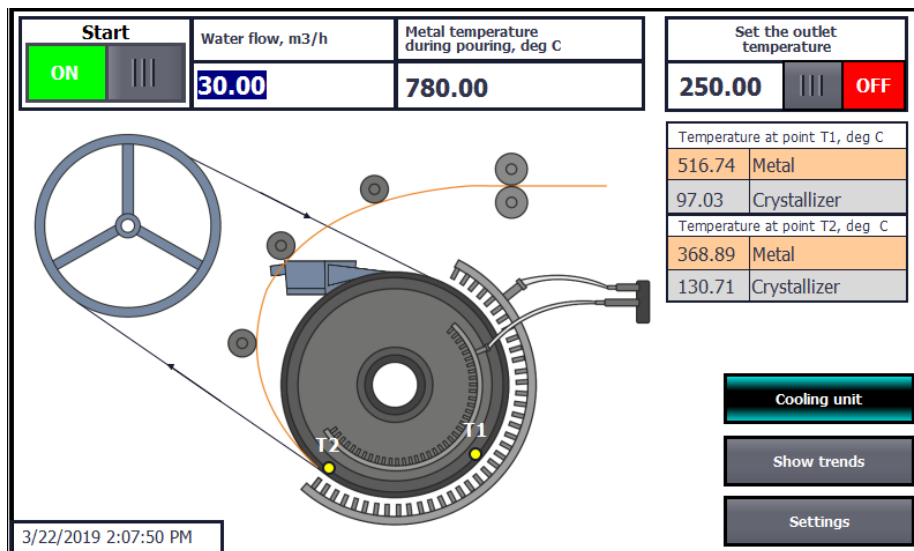Figure 4 shows the program window with a rotary mold.



Figure 4. Window "Rotary mold"

At the top of the mnemonic diagram are located the "Start" button, which allows you to start the execution of the calculation and the "Set the outlet temperature" button, which activates the execution of the control unit for the temperature of the outgoing billet. The unit compares the current temperature of the bar at the exit from the mold with the temperature set by the user in the input field next to the button. The program within specified limits changes with a certain step the water flow for cooling, thereby changing the temperature of the billet.

In the right central part of the operator panel are shown at two points calculated by the model temperature of the metal and the crystallizer. At the bottom of the mnemonic diagram is the "Settings" button (Figure 4), which allows you to change the initial parameters of the calculation.

The following Figure 5 shows the menu for more detailed adjustment of the calculation parameters (the "Settings" button).
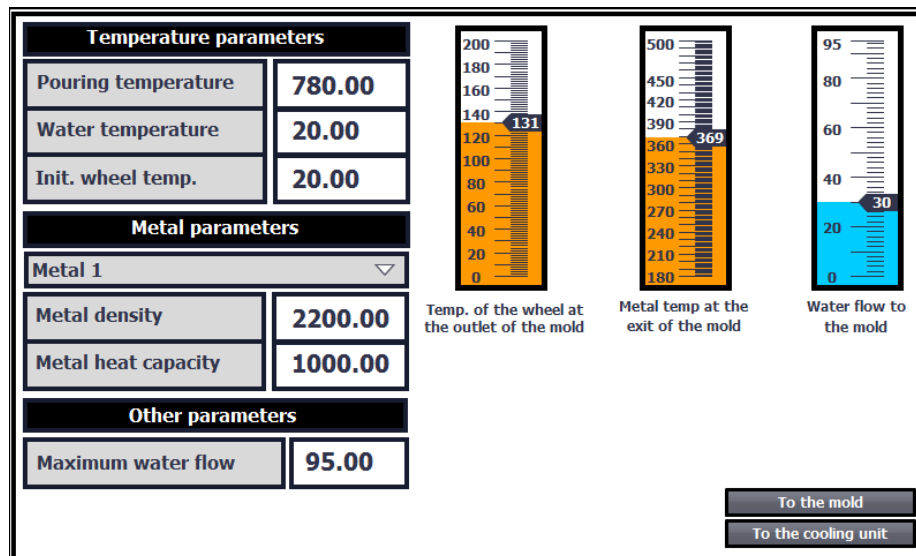
Figure 5. Calculation parameters setup menu

## 4. Results and conclusions

The developed software «virtual casting and rolling lines» allows to calculate the temperature of the metal billet, the casting speed, to debug control algorithms even before commissioning the line, as well as when the alloy changes and the required casting parameters.

The structure of the program allows to "design" the desired sequence of units included in the casting and rolling complex. The unification of the program blocks of the units of machine will allow to perform calculations of various combinations of sequences of casting and rolling units without the need to develop a program for each specific casting and rolling complex.

Calculations of the temperature and velocity of the metal according to the mathematical model are implemented and performed in a microprocessor controller, in this way, the need for additional equipment for modeling is lost, and the control of casting and rolling complex using a process simulator can be carried out without the high level automatic control system of technological process, which is important for individual lines, having a local two-tier APCS.

## References

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